ENGINEERING CASE LIBRARY

ECL 155

RED HEART AT INTERSTATE BRICK COMPANY

While studying ceramic engineering, Wayne Ross worked at Interstate Brick Company which is the largest manufacturer of fired clay products in Utah, with a production of 30 million brick a year. A loss survey conducted at Interstate showed that, at times, 40% to 50% of the total output was rejected and sold as seconds because of "red heart". Bricks with this trait are first quality in physical characteristics, but the face contains a darker pink center or red heart. The problem and Wayne's solution are described in this case.

 Written by Wayne Ross under the supervision of Professor Henry O. Fuchs with the support of the National Science Foundation.

RED HEART AT INTERSTATE BRICK COMPANY

During my junior year at the University of Utah I was employed on a part-time basis as a laboratory technician with the responsibility for all laboratory work of the Interstate Brick Company. The President and General Manager, Harold Cahoon, a Ph.D. in Ceramic Engineering, was responsible for plant engineering.

My assignment was to determine the cause of "red heart" and, with the encouragement of Mr. Cahoon, to reduce the occurrence of bricks with this characteristic.

While observing the sorting of face brick after firing I found that the red heart occurred near the bottom of the hack (a loose stack of brick 12 high which contains 604 brick).

The red heart problem was one they had had for many years. The usual solution was to slow the tunnel kilns down. The bricks are fired in a 325 foot continuous tunnel kiln. The schedule was to fire the brick in slightly over 51 hours. The fireman felt that it would be necessary to slow the schedule to 72 hours to burn out the carbon. This would increase the cost per brick and seriously limit production.

Clays are formed through various geological processes. During some of the processes organic material was mixed with the clay; this organic material is the carbon the fireman referred to.

I went to the literature to find a solution. It was interesting to note that as early as 1908 work had been done on the problem. Also there was a report published just the year before, in 1967. I could not find total agreement among the various authors. However, they did agree that it was necessary to react oxygen with the carbon or organic material to oxidize any sulfur or pyrite present. After carbon and sulfur were removed, the ferrous iron present could be oxidized to the ferric state.

Each of the various references quoted different temperatures or temperature ranges as the most effective for the oxidation process with their particular clay or clays. These varied from 825° F. to 1900° F. The majority centered near the 1600° F. to 1700° F. range.

One important idea which I obtained from the literature is that above 1900° F. any ferrous iron present would flux the surrounding material creating enough liquid to seal the pores and also create the darker red heart. One article also pointed out the importance of the atmosphere during firing.

I knew that the problem was related to oxidation, so some way had to be devised of measuring the rate of oxidation of carbon in the clay. The first method I tried was to use a thermogalvonometric unit which would plot the weight of the sample versus the temperature. The temperature rate or rise was controlled automatically. After working several months it became very evident that the instrument would not differentiate clearly enough between the weight loss of capillary water (chemically bound water) and decomposition of any carbonates, and the weight loss due to the oxidation of the organic material, which was often less than 10% of the total.

It was necessary to isolate removal of the carbon from the other processes. The result was an absorption train (schematic in Figure 1). The sample of clay was placed in the furnace and oxygen was passed over it. Oxygen reacts with the carbon to give carbon dioxide and carbon monoxide. Any carbon monoxide formed is converted to carbon dioxide when it is in contact with the copper oxide. Any SO_3 gas given off is absorbed by the $PbCrO_3$. The remaining gases would pass on through the train. The water vapor that was driven off from the clay was absorbed in the H_2SO_4 solution and the anhydrone drying tube. The CO_2 and excess oxygen were passed through these. The CO_2 was finally collected from the O_2 by passing the gases through bottles containing Asterite which reacts with the CO_2. These bottles could then be weighed and the amount of CO_2 measured. The samples were tested at various temperatures. The weight change with time was determined by alternately weighing the bottles of Asterite. A typical set of results is shown in Figure 2.

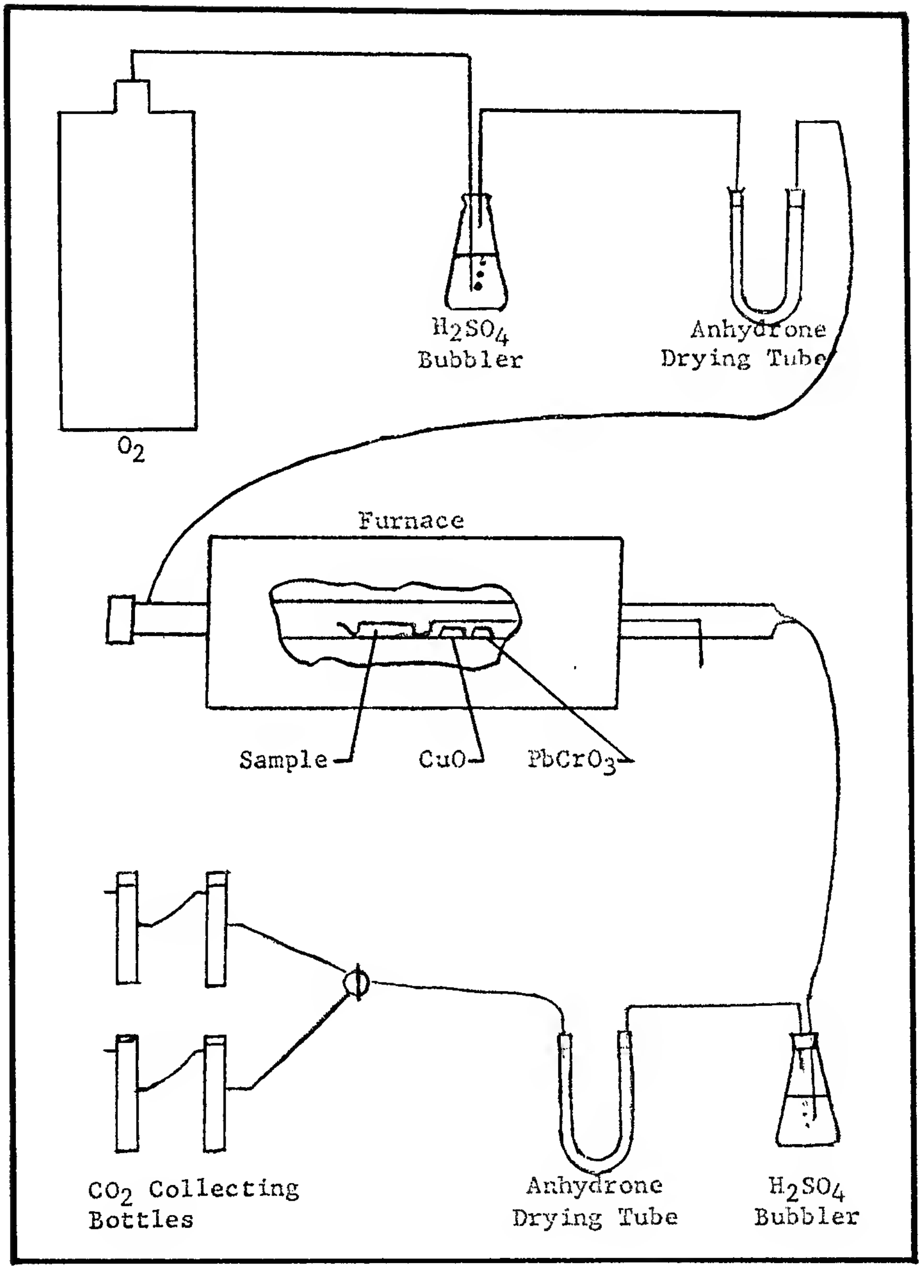
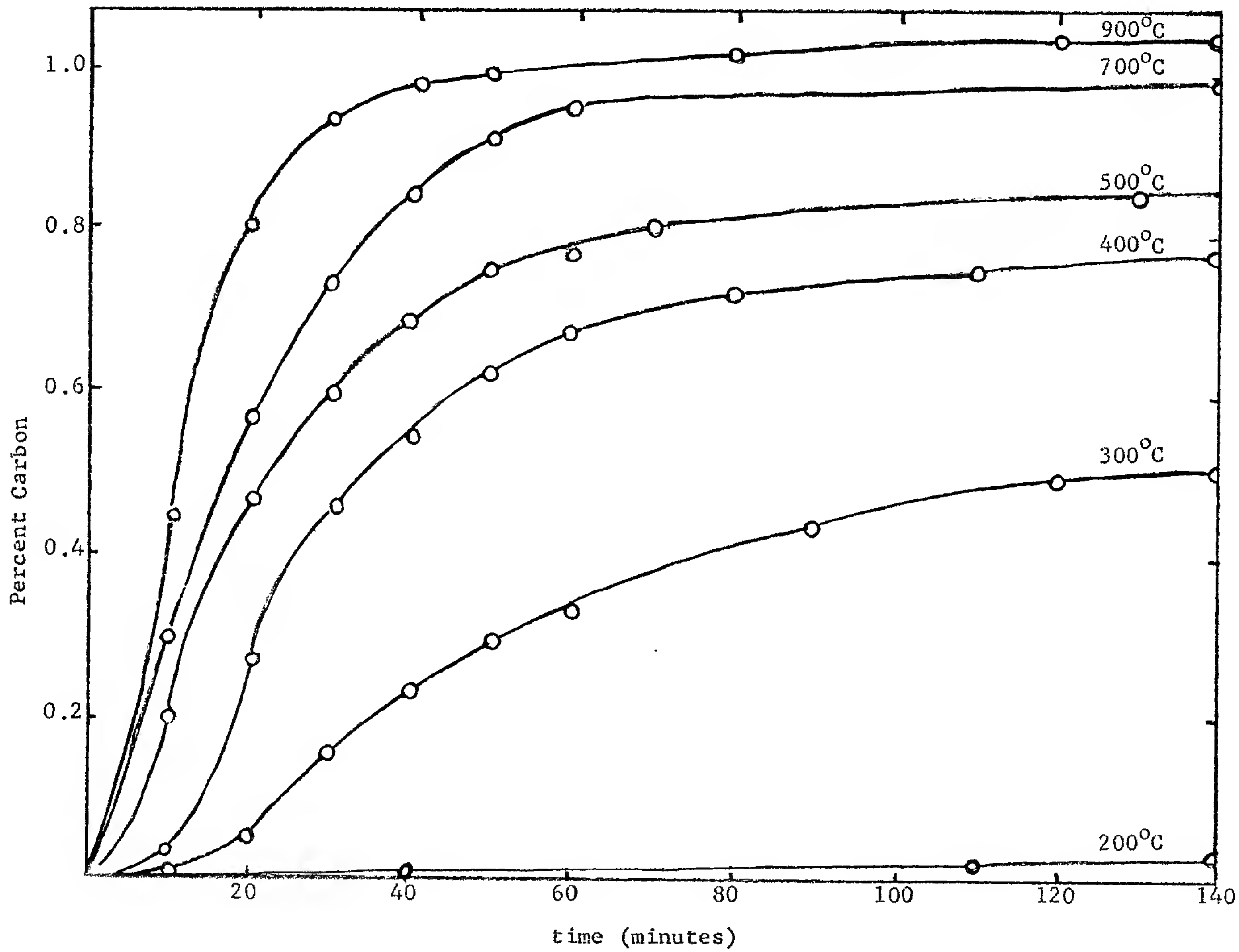


Figure 1

Schematic Drawing of Apparatus for the Measurement of the Carbon and Oxygen Reaction



<u>Figure 2</u>

Plot of Percent Carbon Removed as Percent of Wyoming Clay versus Time of Reaction

From this data I found that the reaction time did increase as temperature increased as is typical of chemical reactions. My results agreed with those favoring the high temperatures.

Plots of the data as shown in Figures 3 and 4 indicate that the reaction is gaseous diffusion controlled. Figure 3 indicates that the reaction is diffusion controlled and Figure 4 verifies that the activation energy for the process is typical for gaseous diffusion.

By examining Fick's 2nd Law of Diffusion it is possible to gain a feeling of the variables.

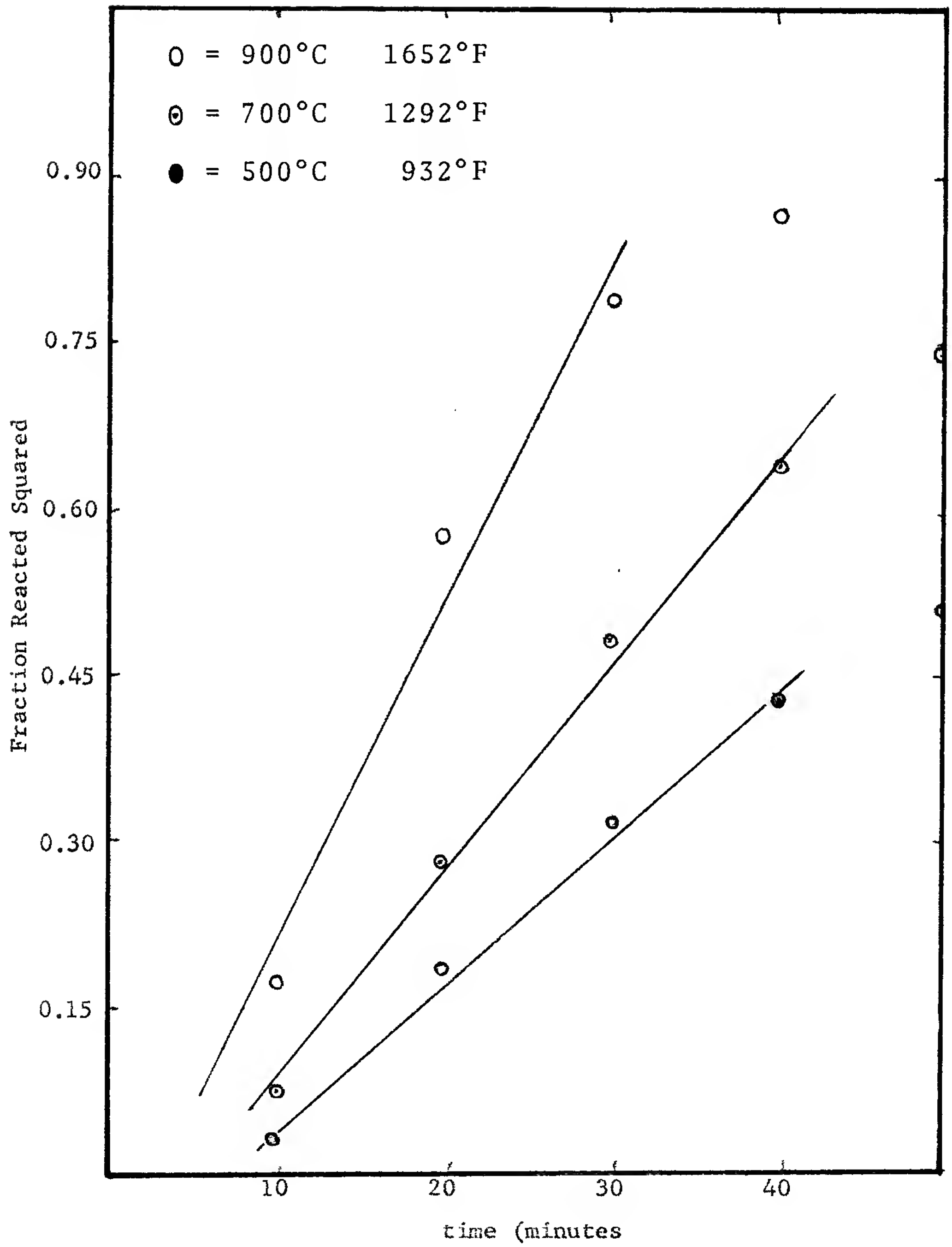
$$m = \int_0^t DA \frac{dc}{dx} dt$$

D, the diffusion coefficient, is a function of temperature. A, the area for diffusion, is related to the permeability of the body which was found to increase with temperature. I also found through other tests that the addition of nonplastic material such as silica sand and grog (ground waste brick) to the batch would increase the permeability. dc/dx, the concentration gradient, could be affected by the atmosphere of the kiln, i.e., the concentration of oxygen. dt, the time is a fourth factor. m, the amount of material oxidized, is the fifth factor.

With the variables identified, the solution lay in the proper use and choice of the variables. Limits were found for each of the variables.

The maximum temperature which could be used was in the neighborhood of 1900° F. This limited D, the diffusion coefficient.

The permeability appeared to increase greatly at about 1600° F. Above 1800° F. for most of the clays it decreased rapidly as the body began to seal. The amount of grog which could be added was also limited by the plasticity of the mixture. Too much grog and the plasticity of the mixture would be too low to extrude.



<u>Figure 3</u>

Plot of Fraction of Carbon Reacted Squared for Wyoming Clay versus Time

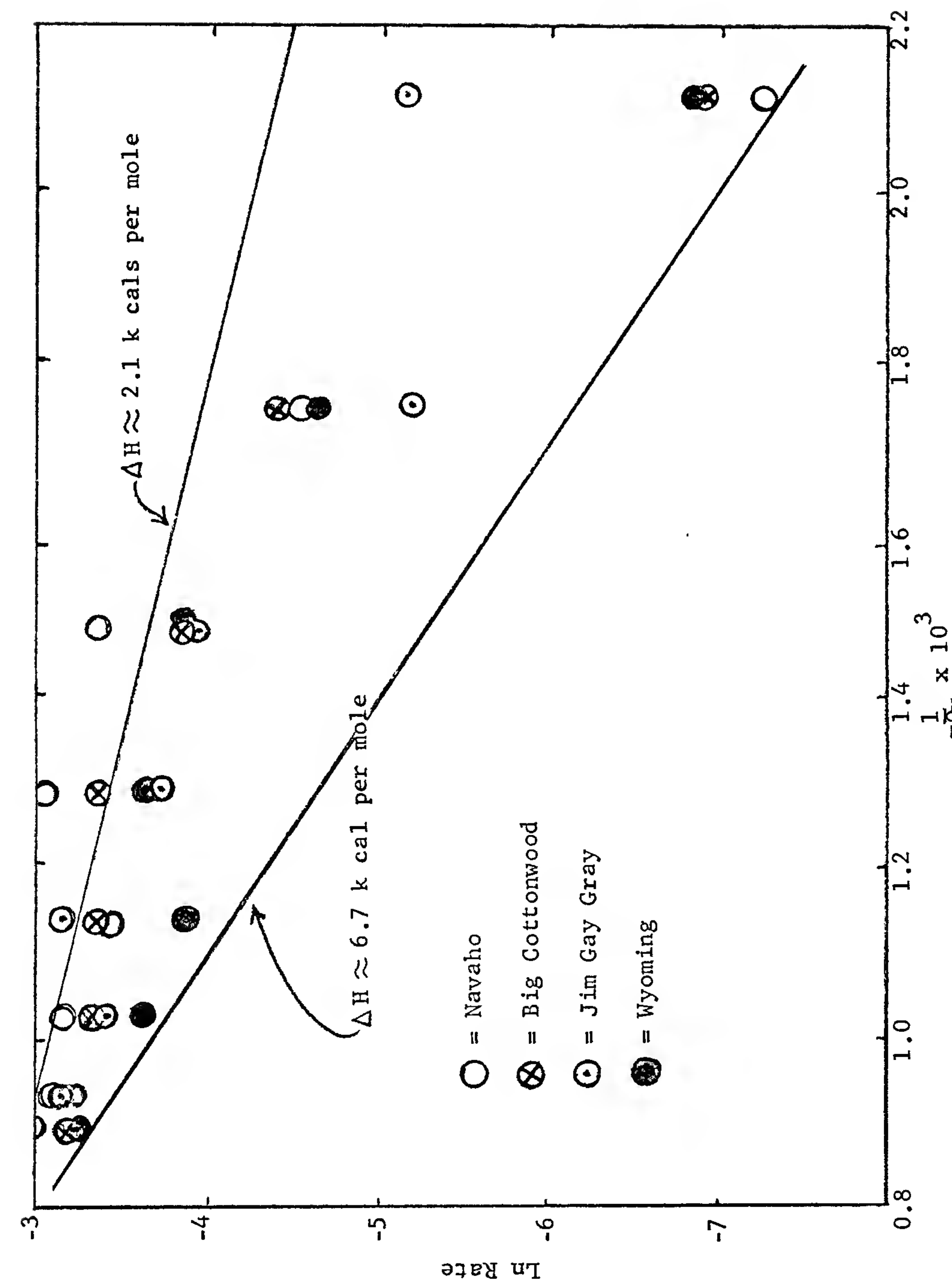


Figure 4

Plot of Natural Log of the
Rate of Change of α (fraction reacted) versus 1/T°K

dc/dx, the oxygen concentration is limited by the need to use air and the use of some of the oxygen in the air for combustion with natural gas for the firing heat. Extra air can be added to the kiln, but at 1600° F the air requires some heat to reach the kiln temperature which means more fuel must be used to provide the heat which raised the costs.

The amount of carbon in each clay varied from about 0.2% to over 1.0%, but the mixtures could not be varied since undesirable color changes would result in the final product. The addition of nonplastics which did not contain any carbon would decrease the amount of carbon present, but it had some problems as noted above.

I had completed my research and now had the summer to apply what I had learned. For my solution I felt that time could not be varied. We needed the brick to fill customer demands. There was hot air available at the cooling end of the kiln. We forced this to the heating end of the kiln as extra air. The extra fuel to heat this was minimal since the brick it was used to cool were near 1800° F. This decreased the percentage of red hearts by about 10%. The next step was an increase in the amount of grog in the body; about a 10% increase was used. I decided at the same time to examine the temperature distribution of the kilns.

The temperature control of the kiln was part automatic and part manual. To aid the fireman in control of the manually controlled area, thermocouples were located in the top of the kiln about every 10 feet. We found that even though the thermocouple readings were identical to those of a previous firing the number of red hearts would sometimes double those of a previous firing.

The burners were located at the bottom of the kiln approximately 5 feet below the thermocouples. There were about 80 burners on the kiln; of these about 30 are automatically controlled. The automatic control is for the hot zone where the final firing temperature is applied to the brick, normally between 1900° F. and 2100° F. It is at these temperatures that the bricks receive their strength and color. The remaining 50 burners are used to bring the brick to the temperature of the hot zone. There are two

types of burners: One type was used initially to begin to heat the brick; the second was used to bring the brick near the temperature of the hot zone.

The thermocouples were reading the temperature at the top of the kiln, but we did not know what temperature was being maintained at the bottom of the kiln or hacks, where the red hearts occurred.

Another common method of temperature measurement in high temperature work is the use of an optical pyrometer. In order to measure the temperature of an object with this method it is necessary to have visual contact with it. In the initial heating zone there are no holes in the kiln wall through which the temperature of the brick could be read.

In the second heating zone visual access was possible to the bottom brick. The fireman and I read the temperature and I then plotted it for him. The plot is shown in Figure 5.

As the graph shows the temperature of the bottom bricks was reaching well above 1900° F. which could create the red heart if the oxidation was not complete.

I then examined the temperature of the initial burners. The burners ranged between 1700°F. and 2250°F. A refractory brick lay between the burner and the bricks being fired. It was not known how much of a temperature gradient existed across this refractory brick. I felt that 2250° F. which would require at least a 350° F. gradient was excessive. I decided to reduce the temperature of the burners to 2000° F. maximum. I also worked with the fireman to smooth out the temperature curve in the second area.

These temperature changes and the addition of grog reduced the red hearts to less than 10% which I felt was a significant improvement. Shortly after this time I left Interstate Brick to continue my education and have not been able to follow up to see if the red hearts have remained reduced in number.

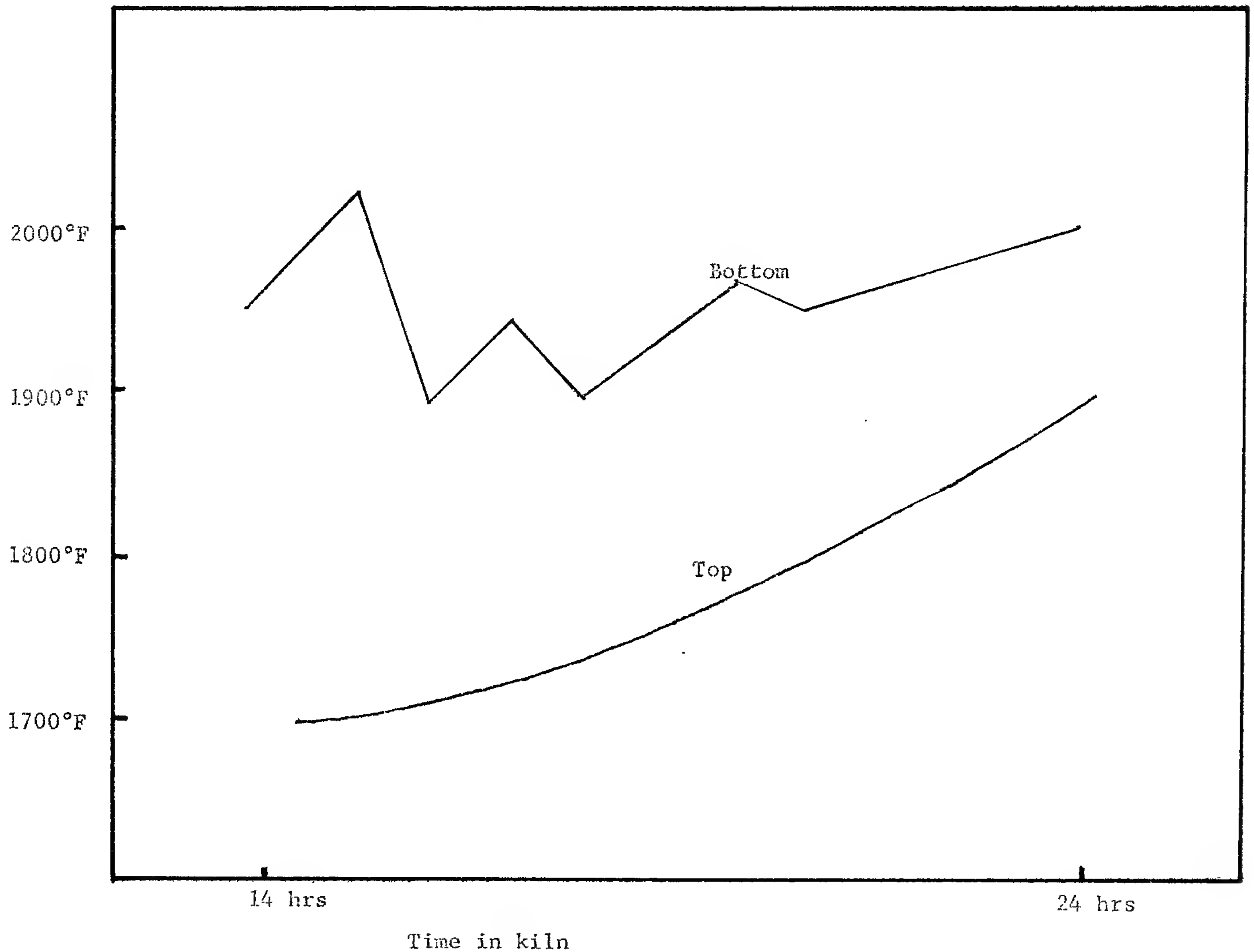


Figure 5

Temperature Distribution in Kiln